THE DEVELOPMENT OF MECHANICAL POWER IN THE LAST DECADE.

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EVEN as we are accustomed to think of history as divided into epochs, having more or less well-defined limits, so the future historian will undoubtedly define the present era probably as the age of the industrial revolution. One of the chief agencies, probably the principal agency, in this revolution is the production of mechanical power.

Few realize, as they go about their daily affairs, how indispensable is this commonplace thing to modern life. Subtract all of its results and see what we have left: rapid transit by stage coach, every convenience depending upon the application of electricity eliminated; home-spun clothes, little variety of food, little or no ice; little communication between distant individuals, few books and no newspapers. In short, subtract everything that is wholly or in part dependent upon power, and how much of the progress of the last thousand years would be apparent?

While we have gone far and fast in the production of power to meet the continually increasing demands of an industrial age, when we consider the lavish supply of materials for its production with which the earth is stored, and the fact that most of it is wasted through ignorance and inefficient methods, we must humbly admit that the art of producing mechanical power is still in its infancy.

In the most successful attempt that man has made to utilize the forces of nature for this purpose, the development of the water fall, he is able to realize only about 33 per cent of the actual power of the water in useful work performed. In plants which derive their power from stored heat energy the showing is much less favorable, the work of the street car in ton miles or the candlepower of the electric lamp being commonly less than two per cent of the equivalent heat energy stored in the coal.

Percentages make little impression on the mind unaccustomed to dealing with these matters. Let us put the statement in a little more startling way. In 1908, an average year,

the production of coal in the United States was approximately 400 million tons. Of this amount 8 million tons actually did some good; the rest was wasted, and wasted at an enormous expense outside of the mere intrinsic value of the fuel. If we figure the cost of mining and marketing coal at two dollars per ton, the loss represented by the handling of 392 million tons of wasted coal amounts to the tidy sum of 784 million dollars, or almost enough to run the United States government for a year. This is over and above the value of the coal.

The actual power value of the coal lost may be illustrated by another example. Take a pound of coal—a lump, say, as large as a man's fist. If all of the energy of the lump could be instantaneously liberated the force would be sufficient to lift its own weight about two thousand miles into the air. If the 490 million tons which are now nonproductive of useful work could all be made available, it would produce 585 million horsepower for a year, twenty-four hours a day. In other words, it would produce all the power used in the United States for twenty years at the present rate of consumption.

For natural gas and petroleum, the other two great sources of power, the showing would be somewhat better.

Consider now all the loss of life at the mines and in transportation, the cost and discomfort of polluting the atmosphere and spoiling structures with smoke, and we begin to get some conception of our enormous inefficiency in dealing with this matter. Our future historian, commenting on the useless waste of life and property in an era like the French Revolution, may have some uncomplimentary things to say about our industrial revolution.

After this discouraging statement of waste and inefficiency, we can appreciate more fully the fact that real progress in improving our methods has been made in the last quarter of a century, and in the last decade the progress has amounted to as much, perhaps, as in the whole previous period of development.

In the earlier designs of prime movers the efforts of inventors were directed mainly to making the wheels go around—no small task in itself—and the attendant waste of fuel was looked upon as more or less unavoidable, or not considered at all. The old wooden water mill wasted fifty times as much water as it used, but it sawed the logs, ground the corn, and

drove the loom. Watt's steam engine, working at an efficiency of probably less than a tenth of one per cent, made the steam plant possible and made the industrial community independent of the water-power site. Stephenson's link motion put the railroad, such as it was, on the map; Fulton built a marine engine that propelled a boat, in spite of the predictions of his friends, and the clumsy and noisy old free-piston engine of Otto and Langen demonstrated the possibility of the modern internal-combustion motor.

Ten years ago the situation in the power world was about as follows:

The perfecting of electrical apparatus had made possible the construction of water-power plants at some distance from the site of the industry to be served. The original American plant of the Niagara Falls Power Company, with its 5000 kw. generating units and 22,000-volt transmission line, was in operation, and represented advanced practice, although more recent designs were in process of construction.

In steam-engineering practice the compound engine had been carried to its logical limit in the huge triple- and quadruple-expansion engines of such ships as the Kaiser Wilhelm. These engines were built in units as great as 15,000 horsepower, and would develop a horsepower-hour on a pound and a half of coal or a little less.

The steam turbine, which began to assume commercial importance about 1900, had reached an efficiency about equal to the best steam engine when built in large sizes. There were two distinct types, called the impulse and the reaction, and one or the other of these types was rigidly adhered to in the construction of a single machine. They were not regarded with great favor for marine propulsion, because they are not reversible. The largest units for land service were 5000 horsepower, and these were looked upon as wonders.

The internal-combustion motor, which began its commercial career about 1890, had reached its greatest perfection in the automobile motor of the period and in the small marine motor. Gas engines for power purposes were built in sizes as large as 50 horsepower, but this was regarded as about the limit. The gas producer was just coming into existence, and gas-engine designers were beginning to think about the problem of larger and more efficient units.

Ten, perhaps fifteen, years ago began what may be called the up-to-date period of power development. As might be expected, efforts in this period have been directed mainly to producing better efficiencies from machinery already developed, yet this period has produced two entirely new power motors and the experimental investigation of a third.

In water-power development, after the successful completion of the American plant at Niagara, many other projects were undertaken. These are of three general classes: medium head plants like the one just mentioned; high head plants like those in California, where the fall is several hundred feet; and low head plants like that at Keokuk, where the head is only about thirty feet. At Niagara the turbine wheels are 5 feet 4 inches in diameter and at Keokuk they are 16 feet 2 inches, while for the high heads that are developed on the Pacific coast an entirely different type, known as the impulse wheel, is used. Progress has been along two main lines: the perfection of wheels to give best efficency for these different sets of conditions, and increase in transmission voltages. We have advanced along these two lines to the point where any sort of a water power may be successfully developed, from an immense volume with little fall to a small volume with a high fall. Voltages have increased from 22,000 to 150,000, and power may be successfully carried 150 miles or more, so that the industry and the town is in a sense independent of the location of the power site.

In steam engineering there has been a return from the complicated triple- and quadruple-expansion engine to the older two-stage compound type. This has been made possible by superheating the steam, that is, raising it to a temperature above that due to its pressure. Development and change in the use of steam turbines has been so rapid in the last decade that it is almost impossible to say what the best practice is at the present time. We are able to distinguish two directions in which changes are being made, but whether they indicate permanent progress the future only can reveal. One of these is increase in size. Where ten years ago 5000 horsepower was regarded as a monster unit it is now regarded as a small one, 30,000 horsepower being the large one. The other direction in which change is being made is in mixing the types, impulse and reaction in a single machine. This enables the designer to take better advantage of the high and low pressures of the

steam as it flows from a state of high to a lower temperature. The turbine is also combined with the reciprocating engine, each forming a stage in a compound unit. In this way the turbine is enabled to get as much power out of a pound of steam after it has expanded to a pressure at which it would be thrown away in a noncondensing plant as the noncondensing steam engine would get out of that pound of steam above that pressure, thus adding a large percentage to the efficiency of the plant.

With every new invention in power machinery comes the statement that the steam engine is doomed and about to be relegated to the museum as a curiosity. This happened when the steam turbine came into use, and it is happening again with the advent of the Diesel motor; but that the steam engine has managed to hold its own is evidenced by the fact that of the total horsepower produced in the United States, after fifteen years of the steam turbine and gas engine, 75 per cent or more is by the reciprocating steam engine. Not only has it held its own as a mechanical device, but its thermal efficiency has been increased to keep pace with improvements in other lines. Speaking roughly, we may say that the efficiency of the steam engine has been practically doubled, both for small and large units, in the last decade. The agencies that have brought this about are the invention of the German uniflow engine, which has an ordinary efficiency about equal to the best multiple-expansion engine working under the most favorable conditions; the locomobile, a combined engine and boiler which will give an efficiency for small plants about as good as the best multiple-expansion engine under the most favorable conditions; the elimination of smoke and consequent saving of fuel; the superheating of steam, which saves the losses from condensation and reëvaporation.

The development in the production of gas power has been mainly in the direction of reliability. In this period gas engines have been perfected to the point where they will *start*, and *run* after they get started. With the perfection in details has come an increase in the size of the units, so that whereas fifteen years ago a gas engine of over 40 horsepower was the exception, we now find them running successfully in units of several hundred horsepower.

The gas-producer plant has shown less development, perhaps,

than any other type of power plant during this period. Perhaps the time for its development has not yet arrived. It may be waiting for the notion of the great central power plant to get more firmly fixed. Distributed over the country are enormous deposits of lignite coal. This coal is worthless as an ordinary fuel, but it may be burned in properly constructed producers and give a fuel efficiency nearly as great as that of good steam coals. Probably this type of plant will not be greatly used until the railroads and scattered industrial plants give up their own little wasteful units and learn to take their power from great central plants located at the mines and distributed through high-voltage transmission lines, as is now coming to be the practice in water-power installations. In connection with gas engines this decade has seen the invention of a new type of unit that, so far, excels in efficiency anything previously devised. This is the constant-pressure engine, known as the Diesel motor. The thermal efficiency of this engine is over 30 per cent under actual working conditions. What this means may be gathered from the fact that it has reduced fuel consumption from one and a half to less than a half pound per horsepower-hour. As a marine engine it has multiplied the steaming radius of vessels by three, and the fact that its fuel is liquid makes it possible to store and handle it with much greater economy than is possible with coal. Engines of this type have been in operation in Germany on the tarry byproducts of petroleum and asphaltum, heretofore wasted; so that power has actually been produced, not only at no cost, but its production has disposed of an otherwise inconvenient waste material. Why should not the gas producer, using lignite fuel, produce gas for the common gas engine, and at the same time supply fuel for the Diesel motor in the form of the troublesome tarry products that now form one of the disadvantages of the producer plant. We should then have our great central station operating at an efficiency now unthought of, and using a fuel which is at present almost useless. This development remains, perhaps, for the next decade.